



A storm near the San Juan Islands.

UNCERTAIN FUTURE

Changes in Climate

Changes in the chemical composition of the global atmosphere can have dramatic effects on the global climate system, which, in turn, controls climate conditions in the Pacific Northwest.

Global climate change

Though they comprise in total less than 0.04 percent of the atmosphere, greenhouse gases matter greatly because they absorb and give off infrared energy, thereby keeping the earth warm.¹ Geologic history shows that increasing

greenhouse gases in the atmosphere leads to an increase in air temperature at the surface of the earth. During the past roughly 700,000 years, for example, variation

in atmospheric concentrations of carbon dioxide between 180 and 280 parts per million by volume (ppmv) coincided with seven cycles between glacial and more mild (interglacial) conditions in which global average temperature changed by 9–14°F (5–8°C).² These cycles brought massive changes, including large-scale changes to the earth's physical appearance, such as ice sheets over Puget Sound and reorganizing of diverse ecosystems.

The composition of the global atmosphere is changing again, this time faster than in past glacial-interglacial cycles.³ During the past 150 years, human activity (chiefly the burning of coal and oil) has raised the abundance of atmospheric CO₂ 32 percent to the highest levels in at least 20 million years (375 ppmv).⁴ Methane, nitrous oxide and other greenhouse gases have also increased significantly due to human activities.⁵

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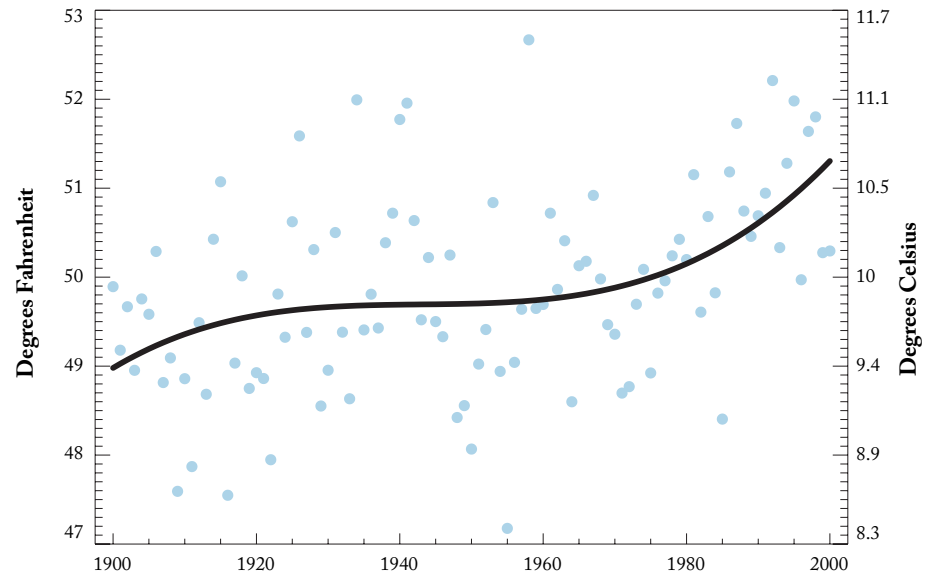
Indeed, during the 20th century earth's average surface air temperature rose about 1.1°F (0.6°C). Most climate scientists are convinced that a substantial portion of that warming is a result of human activity. Continued warming is expected in the 21st century as a result of observed past and expected future increases in greenhouse gases. Projections for the 21st century estimate an additional increase in global average temperature in the range of 3–10°F (1.4 – 5.8°C).⁶

Because of lags in the climate system (for instance, the gradual absorption of atmospheric heat by the ocean), warming and sea level rise will continue for centuries even if concentrations of greenhouse gases in the atmosphere were stabilized today.⁷ The ultimate magnitude of change that occurs depends on the total amount of greenhouse gases emitted until now and into the future.

20th century climate change in Puget Sound

The Puget Sound region warmed at a rate substantially greater than the global warming trend—average annual temperature increased 2.3°F (1.3°C) during the 20th century (Figure 2). Every climate record in the area showed a warming trend and rural climate stations have warmed just as much as urban stations. Much of this warming took place in the second half of the 20th century. Winter warmed 2.7°F (1.5°C) just since 1950.⁸

In addition to responding to changes in global climate (such as global warming), regional changes in temperature can be influenced by the atmosphere's ability to shift heat from one place to another.⁹ In the Pacific Northwest, the Pacific Decadal Oscillation (PDO) is one climate pattern that shifts heat across regions of the Pacific Ocean as it cycles between warm and cool phases.¹⁰ Some portion (perhaps one-third) of the observed Pacific Northwest warming trend in winter (between 1900 and 2000) seems to be the result of natural variation in North Pacific climate.¹¹ The rest of the trend in winter is probably partially due to other natural climate variations; scientists cannot yet



20th Century Warming Trends

say exactly how much each has contributed to the observed 20th century trend.¹²

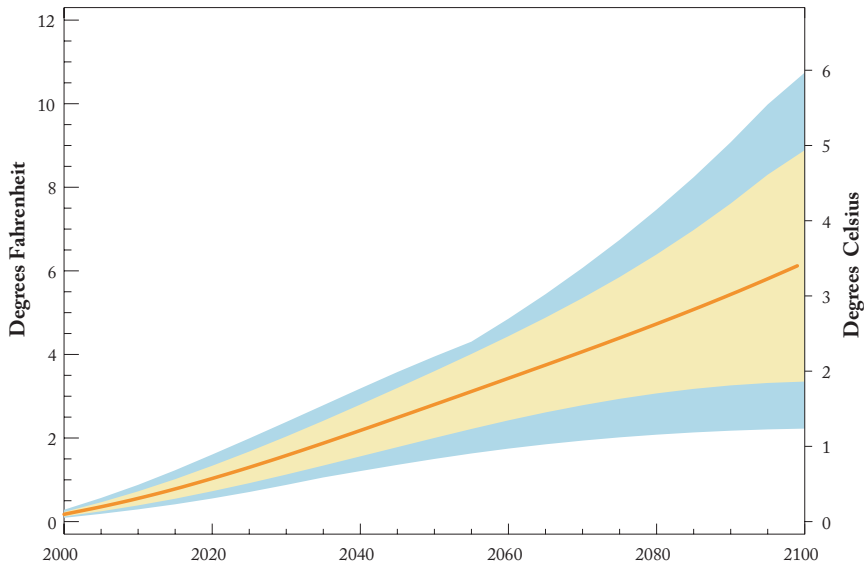
In addition to trends in average conditions, several other temperature-related climatic parameters are ecologically important. Ecosystems are sensitive to how conditions vary, such as temperature variations between day and night and between seasons. The frequency and severity of extreme cold conditions, which serve to control certain pests but also can damage certain plants, can also be important. Changes in all of these parameters have been observed in the Pacific Northwest.¹³

During the 20th century, extreme cold conditions became rarer. Low temperatures rose faster than high temperatures. This is true both of day-night differences and of winter-summer differences.

While changes in temperature over recent decades have been uniformly and consistently positive across the Pacific Northwest, precipitation has fluctuated on a wide range of timescales with no clear trend over the century. Since 1950, precipitation in the Pacific

Figure 2: Average air temperature for the Puget Sound region formed by averaging observations from five representative monitoring stations. Each year's temperature is shown as a circle and the smooth curve indicates that average temperature increased 2.3°F (1.3°C) from 1900 to 2000 and 1.6°F (0.9°C) from 1950 to 2000.

“The Puget Sound region warmed at a rate substantially greater than the global warming trend.”



Northwest Warming Trends

Figure 3: Projected changes in annually averaged temperature for the Pacific Northwest, compiled by considering climate scenarios from 10 global climate models each using two scenarios of future socioeconomic growth. The orange line shows the average of all the models. The blue shading indicates the range from highest to lowest, and the yellow shading indicates the range in which about two-thirds of the scenarios fall.

Northwest has generally declined. As with temperature trends since 1950, the 1977 PDO transition accounts for some, but not all, of this trend.

21st century climate change in Puget Sound

Climate models project a warming rate in the Pacific Northwest of roughly 0.2-1.0°F (0.1-0.6°C) per decade at least to 2050, with average warming of 1.8°F (1.0°C) by the 2020s and 3.0°F (1.7°C) by the 2040s (Figure 3), relative to 1970-1999 average temperature. Even the lowest estimated warming would change the Northwest's climate significantly

still largely fall within the range of variability observed in the 20th century.¹⁴

Characteristics of the environment that respond primarily to precipitation (such as stream flow in a river fed solely by rain) have probably already experienced the range of variability that they will experience in the next century, whereas those that respond primarily to temperature are likely to continually encounter new conditions.

Systems that are tuned to both temperature and precipitation patterns, such as the plants and animals of the Puget Sound region, are also likely to find the conditions of the 21st century different from what they have previously experienced.

“Even the lowest estimated warming would change the Northwest’s climate significantly more than the warming of the 20th century.”

more than the warming of the 20th century. Most models suggest modest (0-10 percent) increases in winter precipitation and in annual precipitation by mid-21st century; these changes are less certain than warming and will



Center for Whale Research

The orca is one of the most recognizable symbols of the Puget Sound region. Climate change will affect orcas, which are at the top of the food chain, as well as phytoplankton, which are at the bottom of the food chain. Given the complex interrelationships among all the living components of Puget Sound, it's impossible to make detailed projects of what climate change may look like, but scientists can draw several likely conclusions. See the chapter starting on p. 26 for more details.